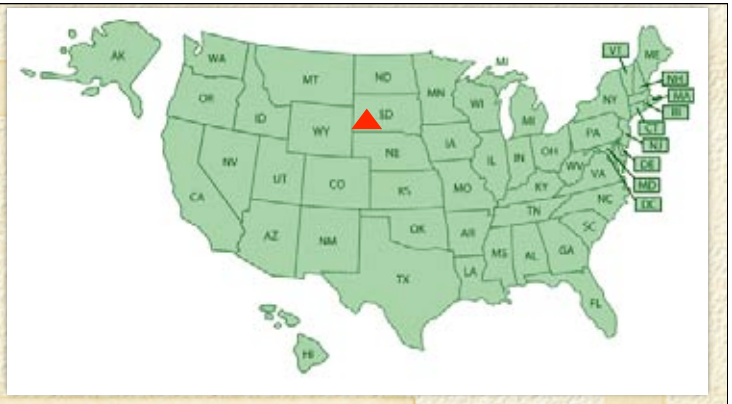
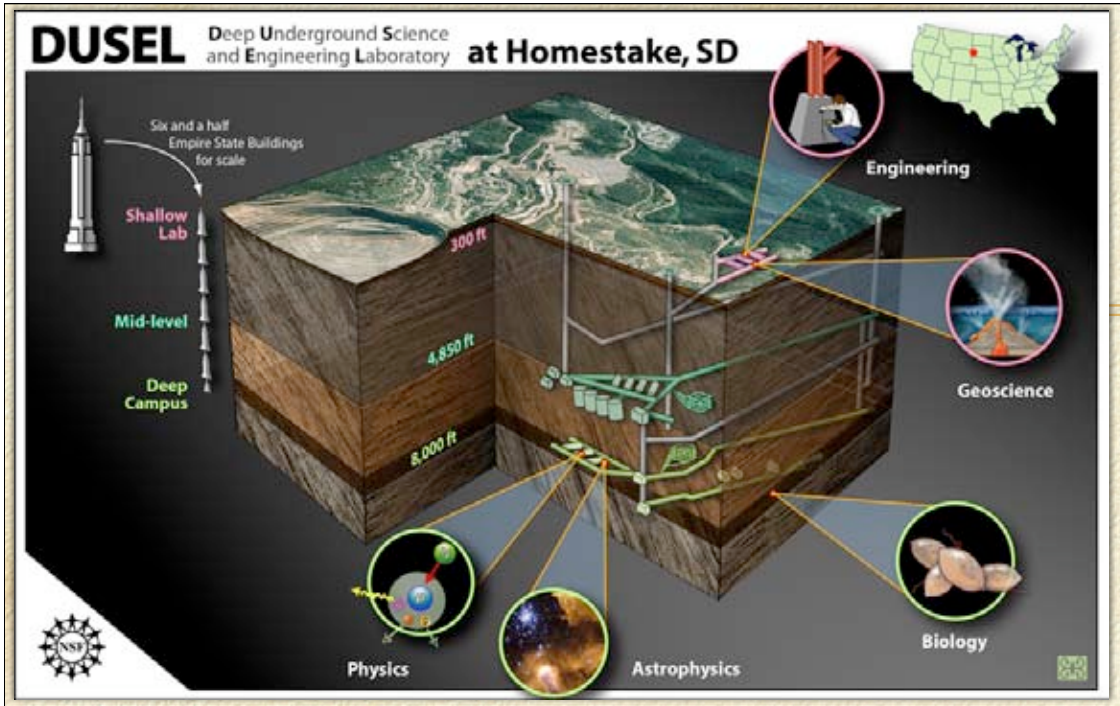


Deep Underground Science and Engineering Laboratory at Homestake

Kevin T. Lesko
UC Berkeley and Lawrence Berkeley National Laboratory
11 October 2007



Outline of Presentation

1. The US National Science Foundation's Deep Underground Science and Engineering Laboratory (DUSEL)

2. Assessment Underground Laboratory Criteria & Requirements

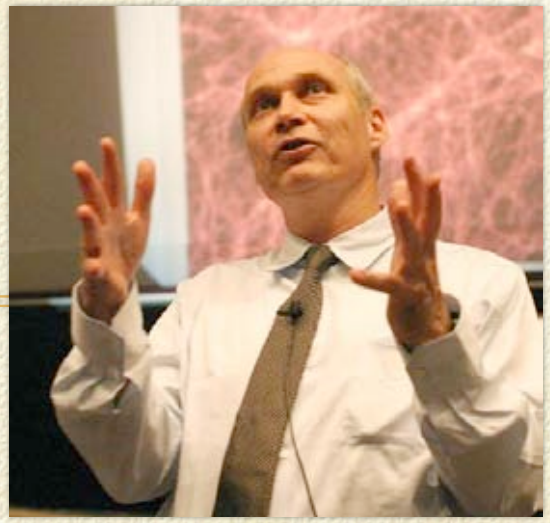
3. Progress in establishing an Underground Laboratory at Homestake and the Sanford Laboratory Early Options for Science

The Vetting of DUSEL

2000 2005 2010

NuSAG 2005, 2006
Dark Matter SAG 2006
EPP2010
HEPAP 2006
Site-selection
S-1 Complete
CDRs Review
EarthScope 2005
Physics of the Universe 2004
S-2 Awards
1st S-1 Workshop
Neutrino Matrix 2004
NSF DUSEL Reorganization 2004
DOE Facilities 2003
EarthLab 2003, HEPAP LRP 2003
Neutrino Facilities Report 2003 (SNOLab Presented)
NeSS 2002
NP LRP 2002
Quarks to the Cosmos 2002
SNOWMASS July 2001
Bahcall Committee report, March 2001
Nuclear Science Advisory Committee, March 2001
Oakland DNP Town Meeting, Oct. 2000
Working Group on Underground Science
Seattle Neutrino Pre-Town Meeting, Sept 2000
Working Group on Underground Science

NSF Process to Create an Underground Laboratory



- 2004: Turner 3-step Process
  - S-1: site-independent science case
    - Sadoulet leading this effort
  - S-2: site dependent projection on different sites (Conceptual Design Report) 8 applications
    - Homestake and Henderson received awards
  - S-3: Technical Design solicitation competition/*by invitation*
    - Funding in FY10 or 11/*FY09* for DUSEL construction

DUSEL Progress

- **S-1 Led by**
  Bernard Sadoulet,UC Berkeley
  with Hamish Robertson, U.W.;
  Gene Beier, U. Penn; Charles Fairhurst, U. Minnesota;
  T.C. Onstott, Princeton; James Tiedje, Michigan State
  - Conducted extensive workshops, information gathering, discussions with the agencies, foreign laboratories, etc.
- **S-1** Report Released: www.dusel.org - Deep Science
- **S-2** 8 Candidate sites, 2 awards
  - **July 2006** Henderson and Homestake

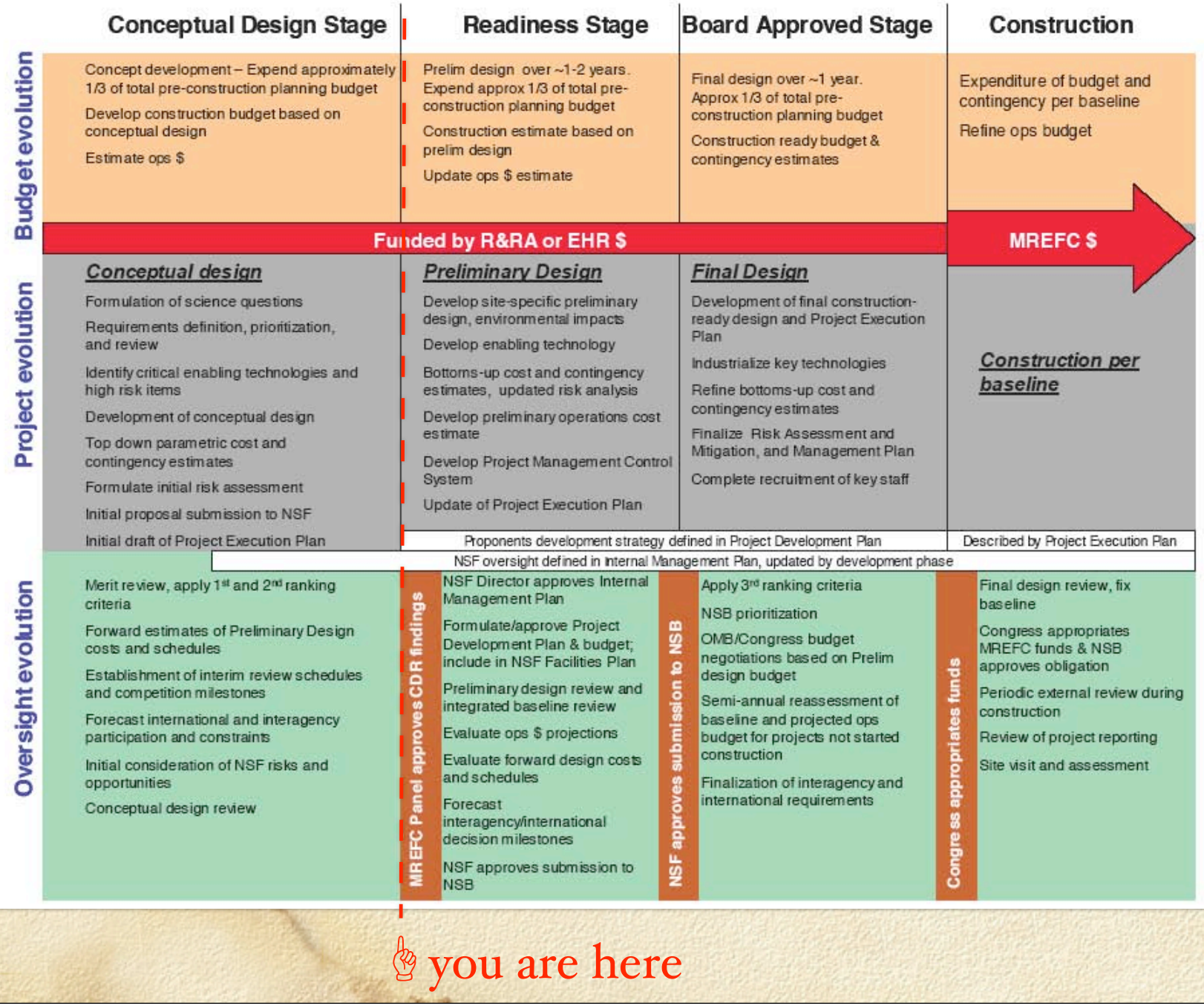
DUSEL Progress

- **August 06** non-competitive review of the two CDRs
- **September 06** S-3 solicitation announced, funds to be provided to develop Preliminary Design, this Report will be the basis for case for DUSEL in the subsequent reviews
- **Fall 06** NSF and DOE announce call for proposals for DUSEL R&D (Jointly reviewed between DOE and NSF)- 50 responses
- **9 January 07** Responses to S-3 Solicitation: 4 proposals
- **9-13 March 07** Review of 4 proposals, including site visits

DUSEL Progress & Remaining Steps

- ☑ **19-22 April 07**, panel review of the 4 proposals
- ☑ **10 July 07** funding for a single proposal to develop advanced plans for DUSEL
  - Next step is to baselined DUSEL plan: Preliminary Design to be prepare for review by NSF, MREFC Panel, NSB, … Development of Final Design, 3 year effort
  - Homestake Collaboration Open, additional participation welcomed and encouraged
- **Summer 07** Call for **Initial Suite Experiments** by NSF (iterative process) S-4 first step
- **FY10/11 DUSEL funding**, include Experiments and Facility
  - Experiments > 50% of ~$500M MRE

Figure 1: *Summary of the pre-construction planning and development process for candidate MREFC projects.*



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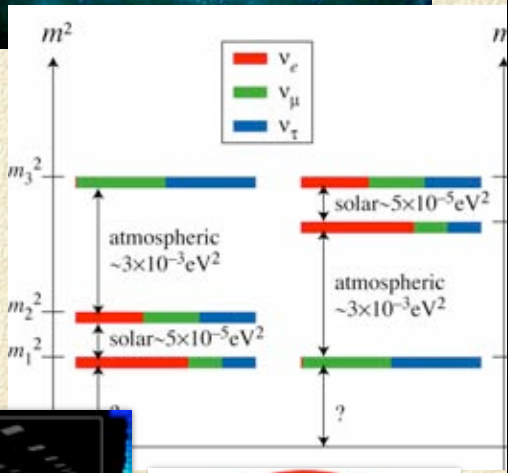
S-1 Findings & Recommendations

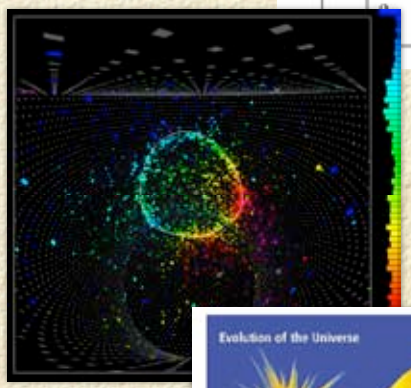
www.dusel.org

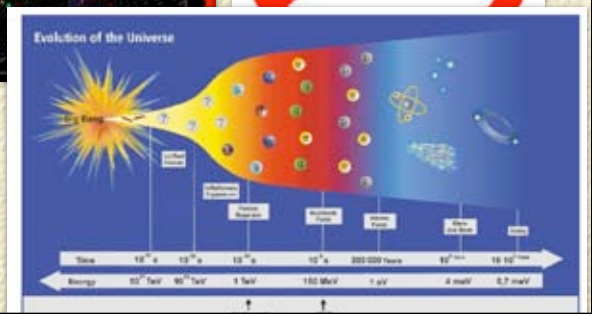
- Findings:
  - Deep underground science is an essential component of research at the frontier
    - Disciplines in transformation
  - Benefits to society
    - Worldwide need for underground space
  - Need for a U.S. world-class deep multidisciplinary facility
- Recommendations:
  - Strong support for deep underground science
  - A cross agency Deep Science Initiative
    - A Deep Underground Science and Engineering Laboratory (6000 mwe, 3000 mwe, 30 to 50 years, ASAP)

Deep Science Questions

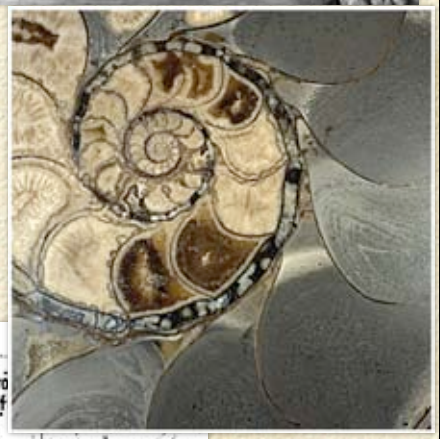
- What is the universe made of?
- What is dark matter?
- What are neutrinos telling us?
- What happened to the antimatter?
- Are protons unstable?
- How did the universe evolve?



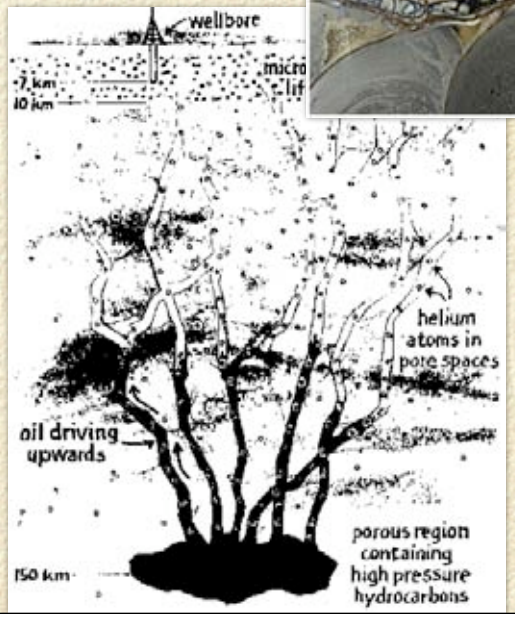




Deep Science Questions



- How do biology and geology interact to shape the world underground?
- How does subsurface microbial life evolve in isolation?
- Did life on earth originate beneath the surface?
- Is there life underground as we don't know it?



Deep Science Questions

- What are the interactions among subsurface processes?
- Are underground resources of drinking water safe and secure?
- Can we reliably predict and control earthquakes?
- Can we make the earth “transparent” and observe underground processes in action?

Deep Science Questions

- What are the mechanical properties of rock?
- What lies between the boreholes?

- How does rock respond to human activity?

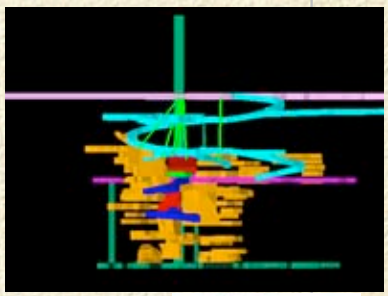
- How does water flow deep underground?
- How can technology lead to a safer underground?

DUSEL: Multidisciplinary, Driven by Physics

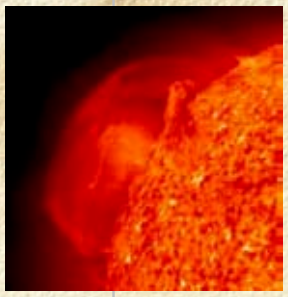
Dark Matter
Cosmology
Astrophysics
Neutron Oscillation

Education & Public Outreach

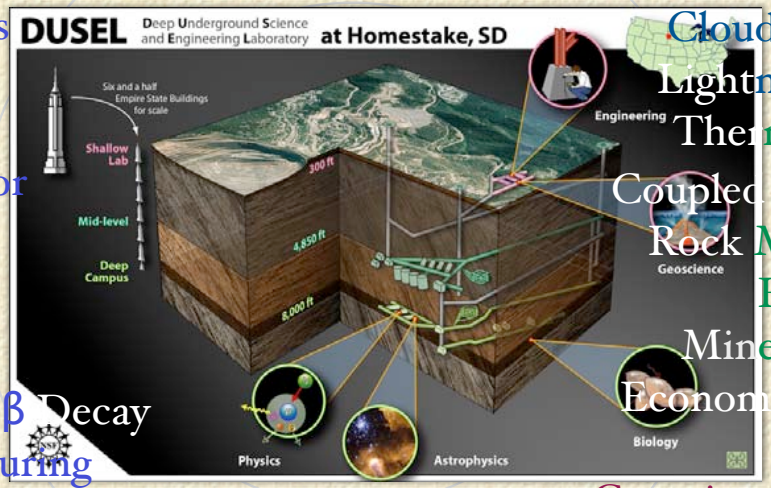
Geo-Database
Geo Modeling



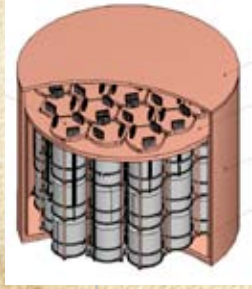
Geophysics
Seismology
Fracture Study



Solar Neutrinos
Geoneutrinos
Underground Accelerator for Astrophysics
Gravity Waves



Cloud Formation
Lightning Physics
Thermal History
Coupled Processes
Rock Mechanics
Hydrology
Mineral Studies
Economic Geology



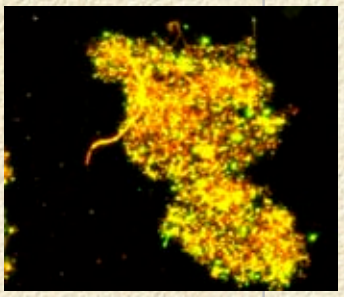
Neutrinoless ββ Decay
U/G Manufacturing
Low Background Counting

Geomicrobiology
Bioprospecting
Life at Extreme Conditions
Geochemistry
Ecology
Environmental Studies

Neutrino Properties
Long-baseline ν Oscillation
CP violation
MNSP Matrix
Nucleon Decay
Atmospheric Neutrinos

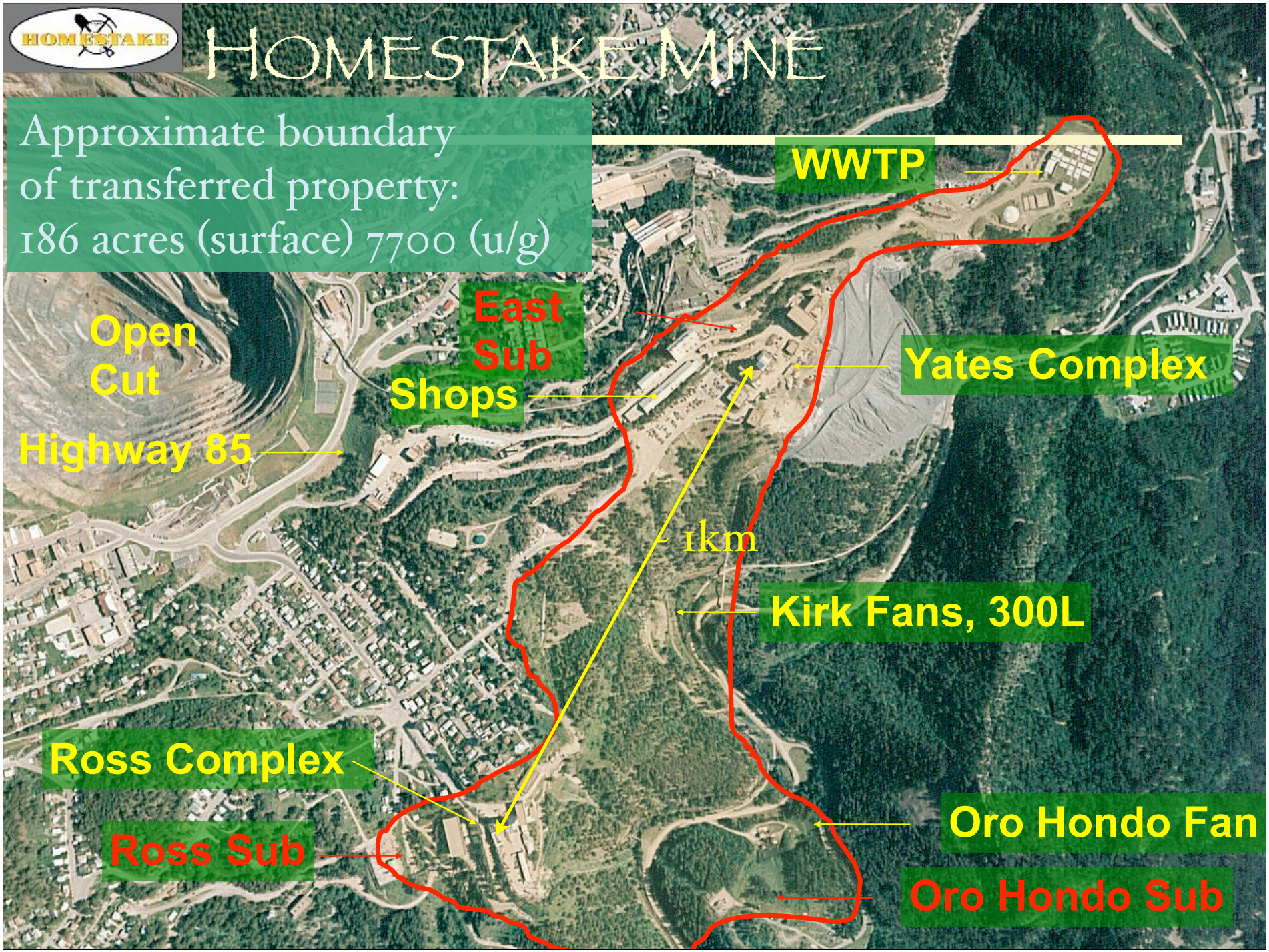
Underground Engineering

Homeland Security

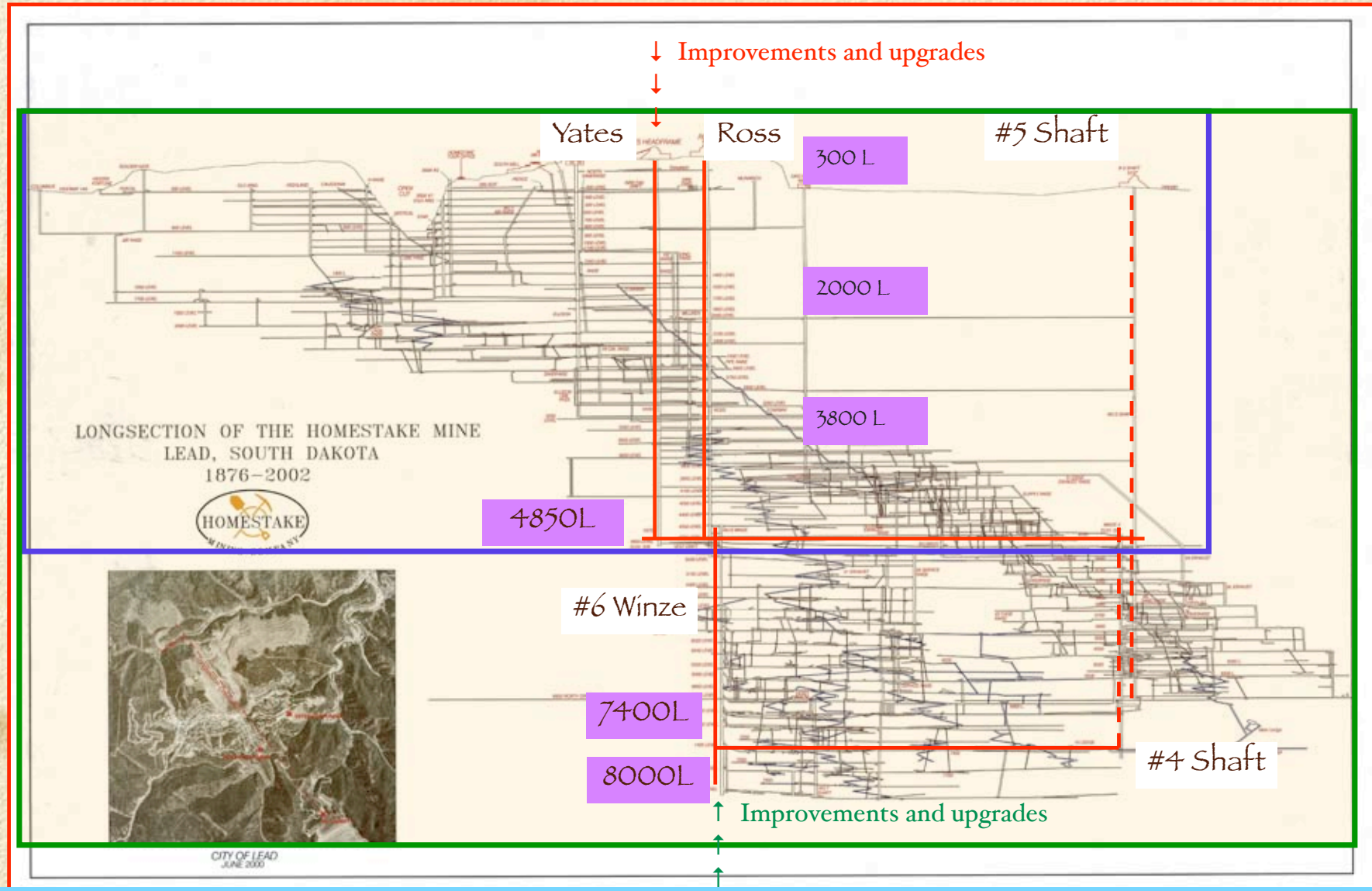


Homestake's Progress

- ☑ October 2005, State Legislature approves additional $20M funding for Homestake, <u>total of $46M</u> from state controlled sources.
  - Rehab plan: $15M
  - Indemnification fund: $10M
  - Operations: $15M
  - Insurance: $2.5M
  - Contingency: $3.5M
- ☑ 1 November 2005 - First call: Letters of Interest for Homestake ~ 85 letters responses
- ☑ Property Donation Agreement Completed 14 April 2006, Property transfered to S.D. May 2006, SDSTA hiring staff to oversee and operate Homestake: ~30 for rehabilitation, ~ 25 to 30 staff members
- ☑ Banker and philanthropist T. Denny Sanford pledges **<u>$70M</u>** to develop Sanford Lab at Homestake
- ☑ Conceptual Design Completed January 2007
- ☑ January 2007 Rehab work initiated
- ☐ Early Implementation Program at Homestake 2007 - 2012 "The Sanford Laboratory"
- ☐ DUSEL Construction funding anticipated in FY11


HOMESTAKE MINE
Approximate boundary
of transferred property:
186 acres (surface) 7700 (u/g)
WWTP
East
Sub
Shops
Yates Complex
Open
Cut
Highway 85
~ 1km
Kirk Fans, 300L
Ross Complex
Ross Sub
Oro Hondo Fan
Oro Hondo Sub

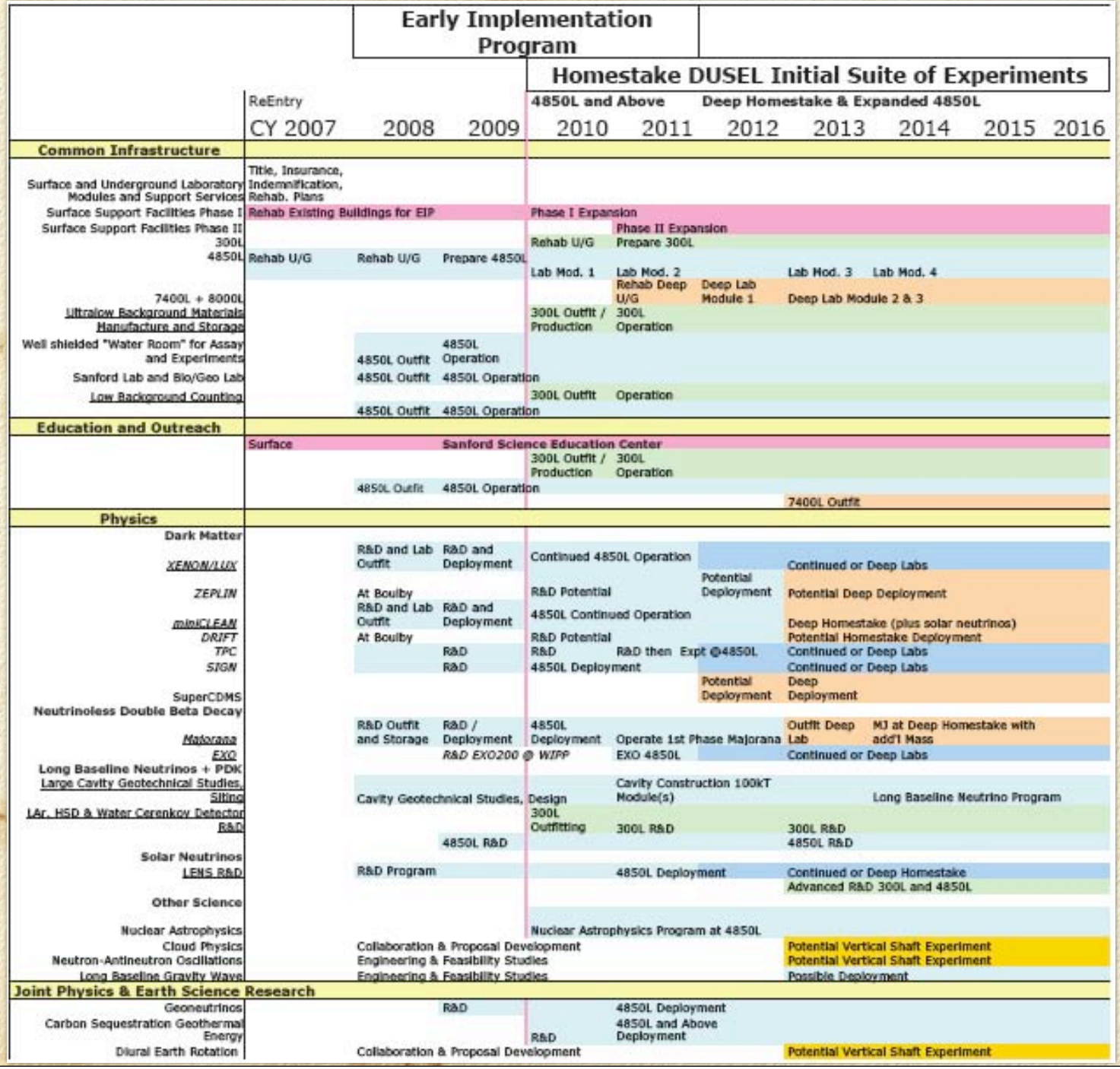
Phased approach to building DUSEL at Homestake

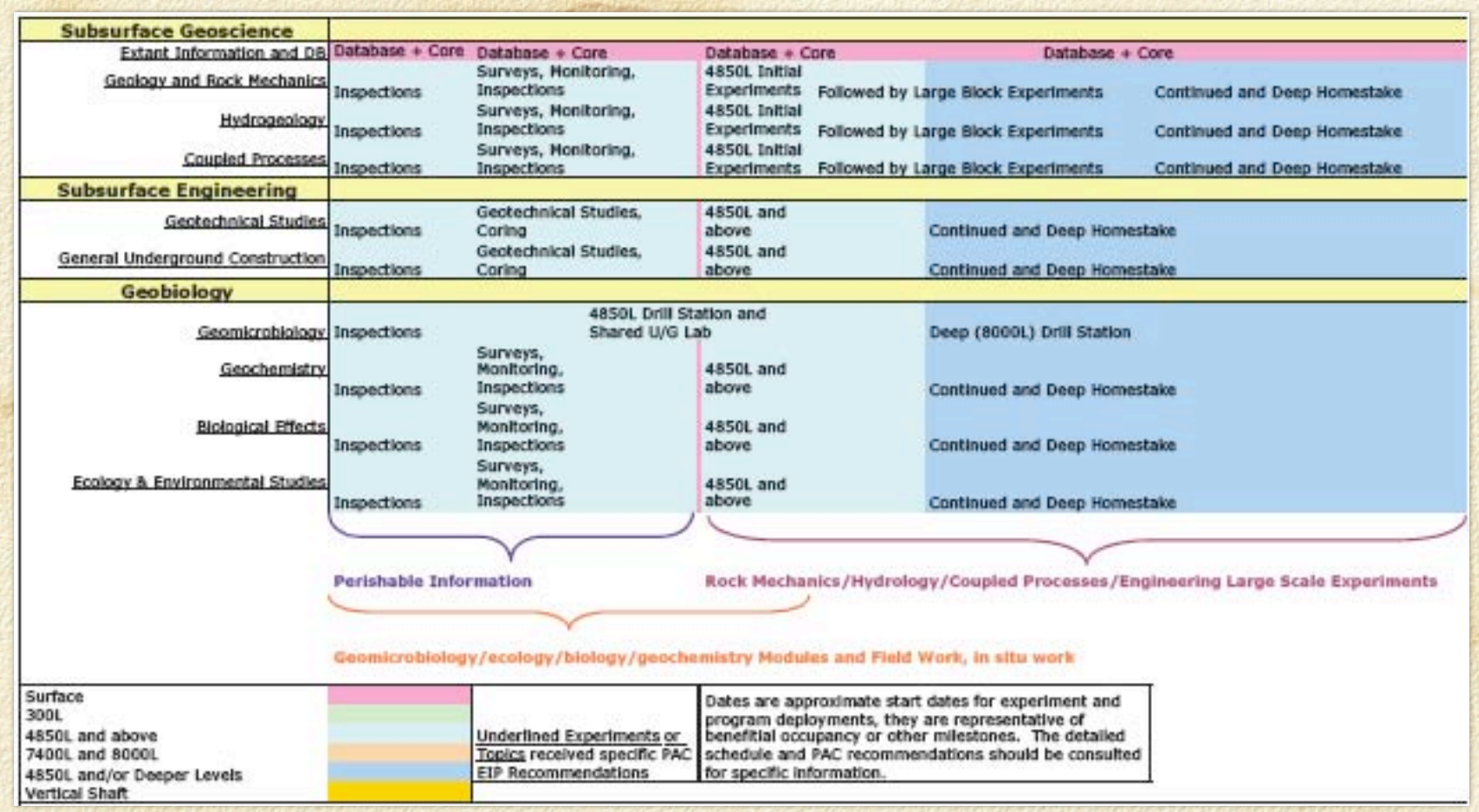


A dedicated science facility without competition or interference from mining, transportation, etc.

Homestake's Early Implementation Program

- Foremost purpose was to preserve Homestake for DUSEL
- Taking advantage of State funded laboratory: 2007 - 2012
- **300 L**, **4850 L**, and other levels, e.g. **2000 L, 3800 L**
- Ross and Yates Shafts refurbished, safe and operating cages
- Basic operations including Safety, Utilities, & Services
- Upgrades and enhancements as budget permits
- International Call for Letters of Interest
- Established Program Advisory Committee


Early Implementation Program
Homestake DUSEL Initial Suite of Experiments
ReEntry
4850L and Above
Deep Homestake & Expanded 4850L
CY 2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Common Infrastructure
Surface and Underground Laboratory Modules and Support Services
Title, Insurance, Indemnification, Rehab. Plans
Surface Support Facilities Phase I
Rehab Existing Buildings for EIP
Phase I Expansion
Surface Support Facilities Phase II
Phase II Expansion
300L
Rehab U/G
Prepare 300L
4850L
Rehab U/G
Rehab U/G
Prepare 4850L
Lab Mod. 1
Lab Mod. 2
Lab Mod. 3
Lab Mod. 4
7400L + 8000L
Rehab Deep U/G
Deep Lab Module 1
Deep Lab Module 2 & 3
Ultralow Background Materials Manufacture and Storage
300L Outfit / Production
300L Operation
Well shielded "Water Room" for Assay and Experiments
4850L Outfit
4850L Operation
Sanford Lab and Bio/Geo Lab
4850L Outfit
4850L Operation
Low Background Counting
300L Outfit
Operation
4850L Outfit
4850L Operation
Education and Outreach
Surface
Sanford Science Education Center
300L Outfit / Production
300L Operation
4850L Outfit
4850L Operation
7400L Outfit
Physics
Dark Matter
XENON/LUX
R&D and Lab Outfit
R&D and Deployment
Continued 4850L Operation
Continued or Deep Labs
ZEPLIN
At Boulby
R&D Potential
Potential Deployment
Potential Deep Deployment
miniCLEAN
R&D and Lab Outfit
R&D and Deployment
4850L Continued Operation
Deep Homestake (plus solar neutrinos)
DRIFT
At Boulby
R&D Potential
Potential Homestake Deployment
TPC
R&D
R&D
R&D then Expt @4850L
Continued or Deep Labs
SIGN
R&D
4850L Deployment
Continued or Deep Labs
SuperCDMS
Potential Deployment
Deep Deployment
Neutrinoless Double Beta Decay
Majorana
R&D Outfit and Storage
R&D / Deployment
4850L Deployment
Operate 1st Phase Majorana
Outfit Deep Lab
MJ at Deep Homestake with add'l Mass
EXO
R&D EXO200 @ WIPP
EXO 4850L
Continued or Deep Labs
Long Baseline Neutrinos + PDK
Large Cavity Geotechnical Studies, Siting
Cavity Geotechnical Studies, Design
Cavity Construction 100kT Module(s)
Long Baseline Neutrino Program
LAr, HSD & Water Cerenkov Detector R&D
300L Outfitting
300L R&D
300L R&D
4850L R&D
4850L R&D
Solar Neutrinos
LENS R&D
R&D Program
4850L Deployment
Continued or Deep Homestake
Advanced R&D 300L and 4850L
Other Science
Nuclear Astrophysics
Nuclear Astrophysics Program at 4850L
Cloud Physics
Collaboration & Proposal Development
Potential Vertical Shaft Experiment
Neutron-Antineutron Oscillations
Engineering & Feasibility Studies
Potential Vertical Shaft Experiment
Long Baseline Gravity Wave
Engineering & Feasibility Studies
Possible Deployment
Joint Physics & Earth Science Research
Geoneutrinos
R&D
4850L Deployment
Carbon Sequestration Geothermal Energy
4850L and Above Deployment
R&D
Diural Earth Rotation
Collaboration & Proposal Development
Potential Vertical Shaft Experiment


Subsurface Geoscience
Extant Information and DB
Database + Core
Database + Core
Database + Core
Database + Core
Geology and Rock Mechanics
Inspections
Surveys, Monitoring, Inspections
4850L Initial Experiments
Followed by Large Block Experiments
Continued and Deep Homestake
Hydrogeology
Inspections
Surveys, Monitoring, Inspections
4850L Initial Experiments
Followed by Large Block Experiments
Continued and Deep Homestake
Coupled Processes
Inspections
Surveys, Monitoring, Inspections
4850L Initial Experiments
Followed by Large Block Experiments
Continued and Deep Homestake
Subsurface Engineering
Geotechnical Studies
Inspections
Geotechnical Studies, Coring
4850L and above
Continued and Deep Homestake
General Underground Construction
Inspections
Geotechnical Studies, Coring
4850L and above
Continued and Deep Homestake
Geobiology
Geomicrobiology
Inspections
4850L Drill Station and Shared U/G Lab
Deep (8000L) Drill Station
Geochemistry
Inspections
Surveys, Monitoring, Inspections
4850L and above
Continued and Deep Homestake
Biological Effects
Inspections
Surveys, Monitoring, Inspections
4850L and above
Continued and Deep Homestake
Ecology & Environmental Studies
Inspections
Surveys, Monitoring, Inspections
4850L and above
Continued and Deep Homestake
Perishable Information
Rock Mechanics/Hydrology/Coupled Processes/Engineering Large Scale Experiments
Geomicrobiology/ecology/biology/geochemistry Modules and Field Work, in situ work
Surface
300L
4850L and above
7400L and 8000L
4850L and/or Deeper Levels
Vertical Shaft
Underlined Experiments or Topics received specific PAC EIP Recommendations
Dates are approximate start dates for experiment and program deployments, they are representative of benefitial occupancy or other milestones. The detailed schedule and PAC recommendations should be consulted for specific information.

Experiment Name	PI(s)	Institution	Letter of Interest	Memorandum of Understanding	Brief Description
LUX: Development of a large liquid xenon dark matter detector	Rick Gaitskell Tom Shutt	Brown Case Western	Yes	Yes	Direct Detection of Dark Matter using cryogenic liquid Xe, detection of signals and separation of signal from background using scintillation light. Detector requires several meters of water shielding to reduce backgrounds. 4850L Davis Cavity is appropriat
Collaborative Research Towards Transparent Earth	Steven Glaser Lane Johnson Bill Roggenthen	UCB UCB SDSM&T	Yes	Yes	This proposal presents a plan to install and operate a permanent seismic observatory illuminating the volume of the Homestake Mine from all six possible directions. We have chosen the Homestake DUSEL site because it offers a unique opportunity - the large
Low Background Counting Facility, DOE BES ESPSoR	Dongming Mei Bill Roggenthen	USD SDSM&T	Yes	Yes	Develop a state-of-the-art Low Background Assay Facility in the Davis Cavity (4850L)
miniCLEAN	Andrew Hime	LANL	Yes	MOU under discussion	Direct Detection of Dark Matter using cryogenic noble gases.
Liquid Argon Dark Matter	Dongming Mei Andrew Hime KTL	USD LANL LBNL	Yes	MOU under discussion	Direct Detection of Dark Matter using cryogenic noble gases.
Homestake: Biological, Chemical and Geological Sampling	Sookie Bang Mark Conrad	SDSM&T LBNL	Yes	Yes	Site Characterization and baseline establishment for biology, chemistry, hydrology, and geology
Majorana: Neutrinoless double beta decay R&D	John Wilkerson Steve Elliott	U.W. LANL	Yes	MOU being developed August 2007	Development of ultrapure materials, low background counting and Ge detector demonstration module
Large Cavity Development and R&D	Milind Diwan Ken Lande	Brookhaven Penn	Yes	Yes	Develop plans for large cavities and water-Cerenkov detectors for nucleon decay and long baseline neutrino experiments
Carbon Sequestration Experimental Design	Joe Wang Kevin Lesko	LBNL LBNL	Yes	Yes	Development of experimental designs for carbon sequestration facilities and the behavior of super-critical CO2 in the underground

Dark Matter

Geo/seismic array

Low Background Counting

Dark Matter

Dark Matter

Geo/Bio

Neutrinoless ββ

Large Cavities, LBL νs

Carbon Sequestration

Homestake DUSEL Plans

300L R&D, E&O

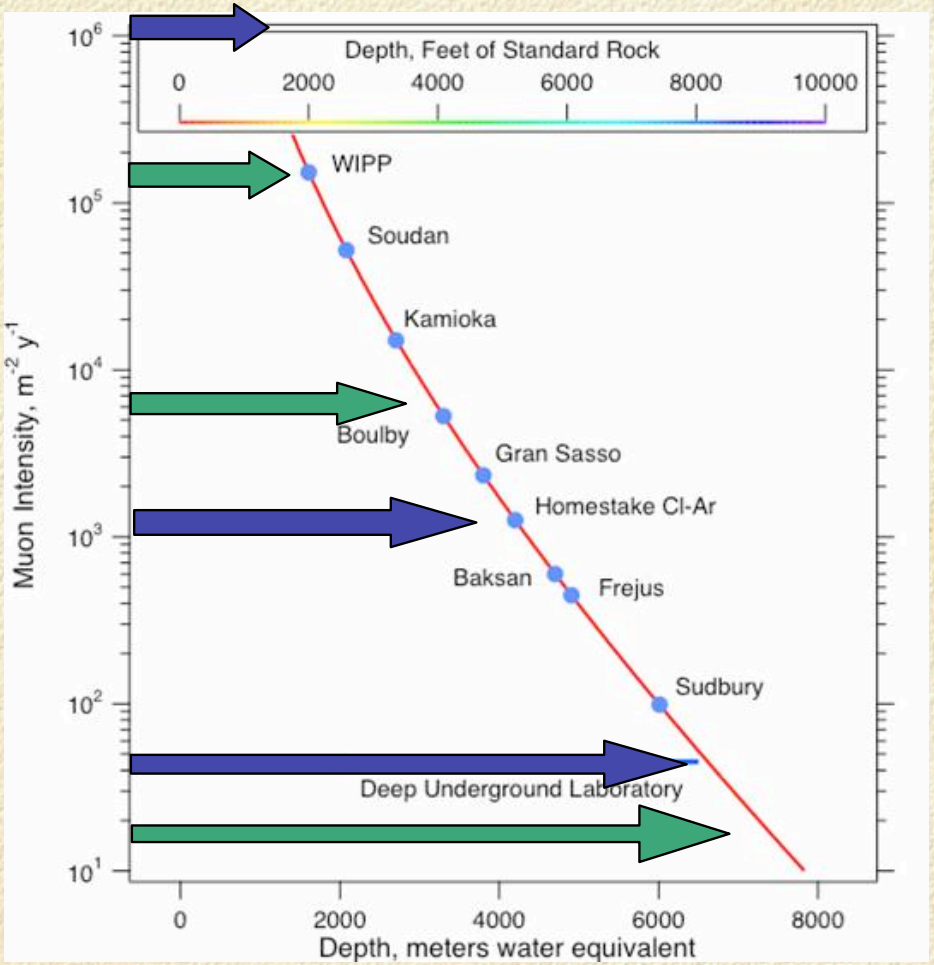
2000L Geo Level

3800L Geo Level

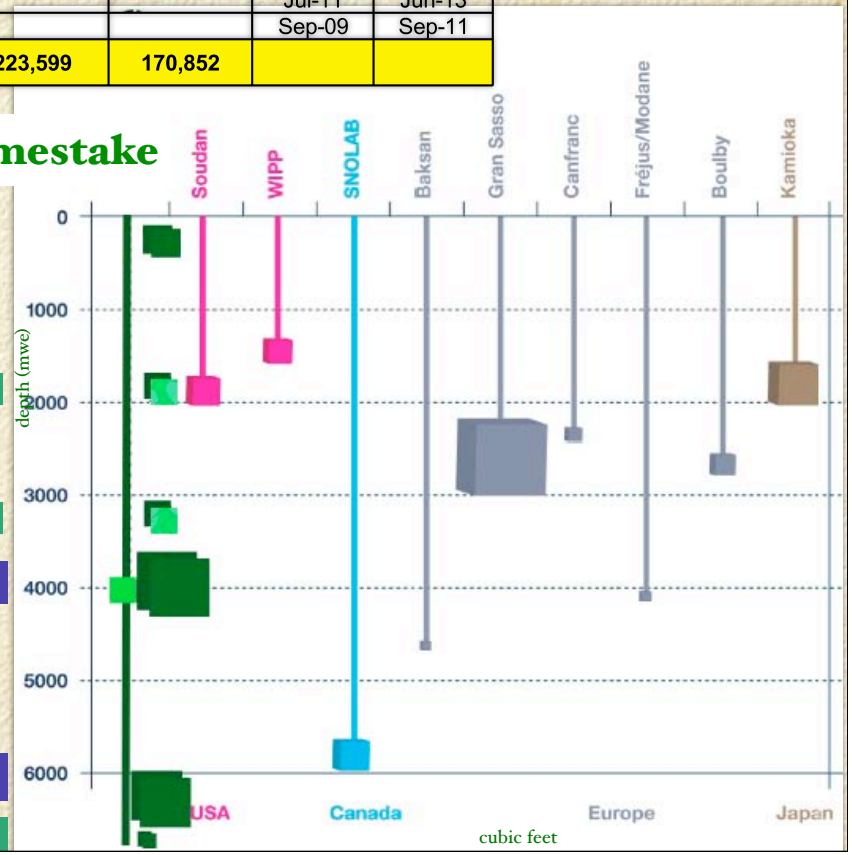
4850L Major Campus

7400L Major Campus

8000L Geo Lab



Homestake Interim Lab and DUSEL Summary of Development of Space and Availability (Underground Space Fully Outfitted and Ready for Detector Installation)		Labs, Shops, Offices Usable Floor Area		Excavation Volume (including access drifts)		Construction Schedule	
		sq. ft.	sq. m.	cu. yd.	cu. m.	Start	Finish
4850 Level	**Subtotal**	**107,351**	**9,973**	**111,115**	**84,903**		
Ross Shops for Construction Staging		12,469	1,158	5,738	4,385	Apr-08	Dec-08
Davis Lab, Sanford Lab, and Bio-Geo Lab		15,738	1,462	13,543	10,348	Sep-08	Jul-09
Lab Module #1 and Common Facilities		26,464	2,459	25,155	19,221	Oct-10	Sep-12
Lab Module #2		17,560	1,631	21,433	16,377	May-11	Apr-13
Lab Module #3		17,560	1,631	23,121	17,667	Sep-13	Jul-15
Lab Module #4 (excavation only, without lab outfitting)		17,560	1,631	22,125	16,906	Aug-14	Jul-15
7400 Level	**Subtotal**	**63,588**	**5,907**	**98,477**	**75,246**		
Lab Module #1 and Common Facilities		28,468	2,645	29,594	22,613	Jan-12	Mar-14
Lab Modules #2 and #3 (excavation only, without lab outfitting)		35,120	3,263	68,883	52,633	Dec-12	Jan-14
300 Level	**Subtotal**	**8,668**	**805**	**14,007**	**10,703**		
Lab #1, Shops, and E&O Rooms		8,668	805	14,007	10,703	Nov-10	Nov-11
Surface	**Subtotal**	**98,000**	**9,104**				
DUSEL Offices and User Support Areas,Phase 1		10,000	929			Dec-10	Jun-12
Sanford Clean Room and Assembly Shop		6,000	557			Dec-10	Jun-12
DUSEL Offices and User Support Areas,Phase 2		32,000	2,973			Jul-11	Jun-13
Sanford Center for Science Education		50,000	4,645			Sep-09	Sep-11
Total		**277,607**	**25,790**	**223,599**	**170,852**		



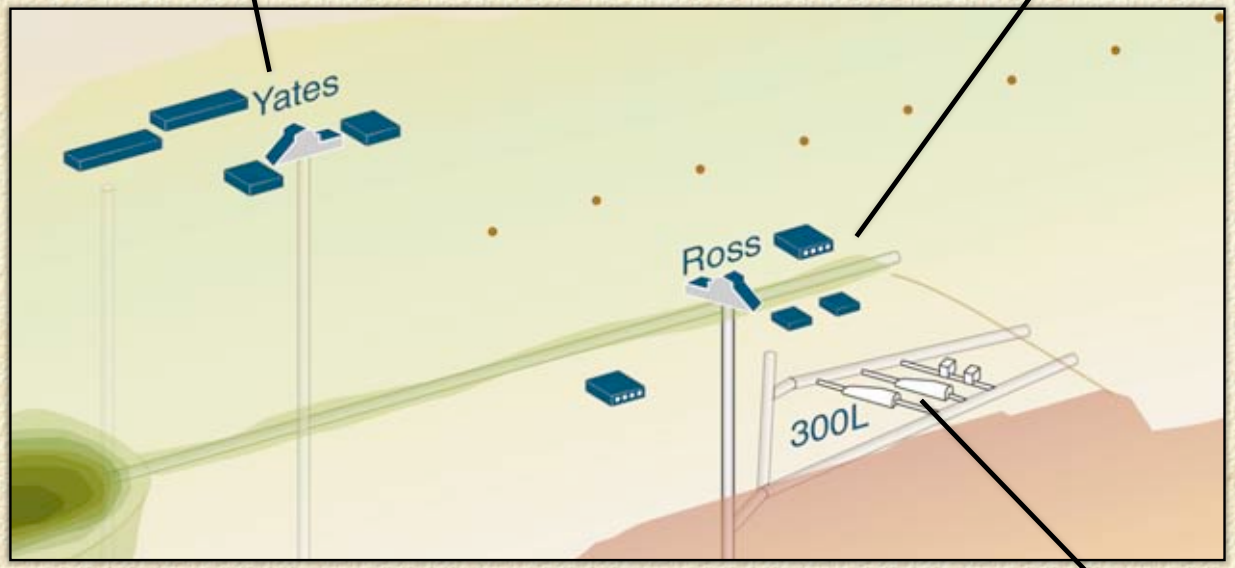
Campus Development Concepts for Surface Facilities and 300 Level

Yates Complex Surface Facilities:

- Laboratory Administration Building and Training
- User Support Services: Clean Room Assembly & Fabrication Shops
- R&D Laboratories, User Offices, Meeting Rooms
- Education and Outreach: Sanford Center for Science Education
- Shipping and Receiving, Storage

Ross Complex Surface Facilities :

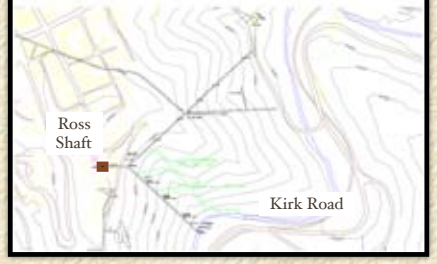
- Construction Materials and Equipment Staging
- Construction Superintendents and Contractor Offices
- Maintenance Shops
- Shipping and Receiving, Storage
- Facility Site Services and Operations



Experiments and Facilities at 300 Level:

- Education and Outreach Classroom and Laboratory
- User Support Shops: Assembly, Fabrication and Underground Storage
- Research and Development Laboratories
- Near-surface Experiments
- Low-background Counting and Calibration Facility

300 Level Campus Plan for near-surface, drive-in access



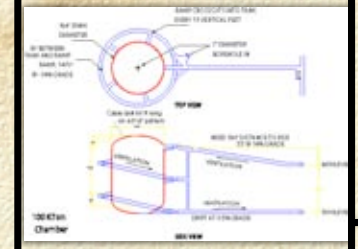
Campus Concepts for Mid- and Deep-level Experiments

Early Implementation Program & Facility Infrastructure Development at 4850L:

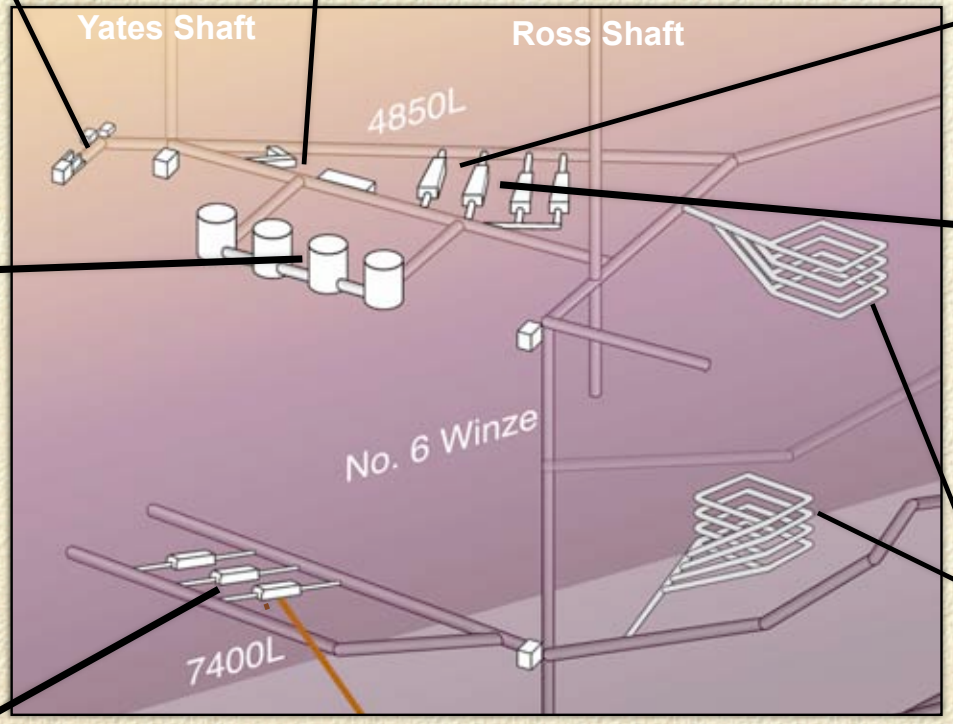
- Low-Background Counting Facility
- Neutrinoless Double Beta Decay
- Dark Matter
- Earth Sciences and Geo-microbiology Lab
- Common Facilities and Clean Room Transition
- Utility Services and Refuge Chamber

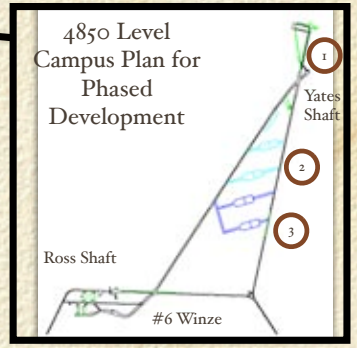
Initial Suite of Experiments at 4850 Level

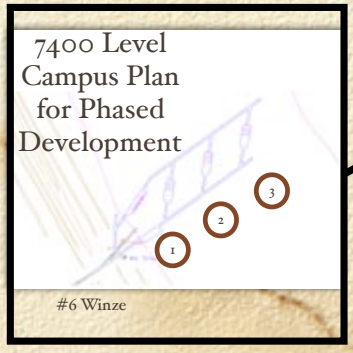
- Dark Matter
- Double Beta Decay
- Nuclear Astrophysics
- Solar Neutrinos
- Geoneutrinos



Design and Excavation concept for future, multiple 100 kTon chambers for Long Baseline Experiment







Geosciences:

Large Block Coupled Processes Experiments

Initial Suite of Experiments at 7400 Level:

- Large Double Beta Decay
- Solar Neutrinos
- Supernovae Detection
- Large Dark Matter

Initial Suite of Experiments

- Main DUSEL Construction to begin in FY10 or 11
  - $250M for the facility
  - $250M for the Initial Suite of Experiments (ISE)
    - Funds to be made available in 2008 to bring the ISE to the same level of "readiness" as the facility, must be submitted together
    - Process to establish the ISE to be determined soon
    - Town Meeting 2 - 4 November 2007 to begin process
    - http://cosmology.berkeley.edu/DUSEL/Town_meeting_DC07/

Homestake PIs, Senior Personnel & Coordinators

- Michael Barnett, LBNL (E+O)
- Yuen-dat Chan, LBNL (Other uses)
- Milind Diwan, BNL (lbl, pdk)
- Reyco Henning, LBNL (ονdbd, dm)
- Ken Lande, Penn (lbl, pdk, geo-neutrinos)
- Bob Lanou, Brown (neutrinos, solar neutrinos)
- Chris Laughton, FNAL (engineering)
- Kevin T. Lesko, UCB (physics) PI
- Stu Loken, LBNL (E+O)
- Hitoshi Murayama, UCB (physics theory, neutrinos)
- Tommy Phelps, ORNL (geomicro)
- Bill Roggenthen, SDSM&T (geophysics) coPI
- Ben Sayler, BHSU (E+O)
- Tom Shutt, Case Western (low backgrounds)
- Nikolai Tolich, LBNL (geonus)
- Bruce Vogelaar, Virginia Tech (solar nus)
- Herb Wang, U Wisc. (geology, rock mechanics)
- Joe Wang, LBNL (earth science, geophysics)

Richard DiGennaro, LBNL, Project Manager and Systems Engineer

Dianna Jacobs, LBNL Project Controls

Liz Exter, Dave Plate, Project Engineering

Mark Laurenti, Mining Engineer

Syd DeVries, Mining Engineer

Dave Snyder, SDSTA Exec. Director

Trudy Severson, SDSTA

SDSTA Engineering and Safety Personnel

Ms. Melissa Barclay & Jeanne Miller

http://www.lbl.gov/nsd/homestake

http://neutrino.lbl.gov/Homestake/LOI

http://neutrino.lbl.gov/Homestake/FebWS

http://homestake.sdsmt.edu/HRB/Refer.htm

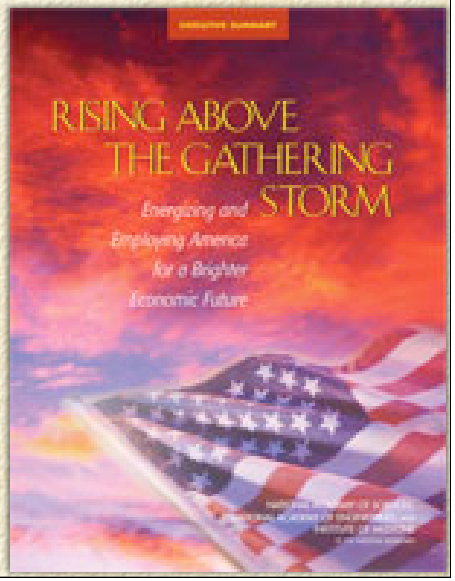
http://neutrino.lbl.gov/Homestake

http://www.dusel.org

Extra slides

Sanford Gift: $70M

- Gift 1: $35M to be made in two installments
  - Gift 1 Part 1: $15M by December 2007
  - Gift 1 Part 2: $20M by December 2008
  - For 4850L laboratory and infrastructure: i.e. lifts, access, custom space, operations, surface space, radon-reduced air, …
- Gift 2: $20M
  - $20M by December 2009
  - Establish the Sanford Science Center (E&O)
- Gift 3: $15M
  - between January 2010 - December 2012
  - For going deep, 7400 level lab



Triggers for the Gift

- Gift 1 - $35M 2007 - 2008
  - NSF selects Homestake as sole candidate site for DUSEL
  - Laboratory is named Sanford Underground Science and Engineering Laboratory (SUSEL-Homestake)
  - SDSTA spends their $ (rehabilitation and re-entry)
  - Significant scientific demand (defining users of EIP)
    - measured by MOUs - $10M

Triggers for the Gift

- Gift 2 - $20M 2009
  - Gift 1 triggers satisfied
  - naming rights - **Sanford Science Education Center**
  - SDSTA develops "business plan" and spends their $ on center
    - Creates ~50,000 ft² education & outreach center
- Gift 3 - $15M 2010-2012
  - Gift 1 and 2 conditions satisfied
  - National funding for the laboratory (NSF, DOE, etc.) to the tune of $15M
  - SDSTA spend their $